Valve Stem Gaskets

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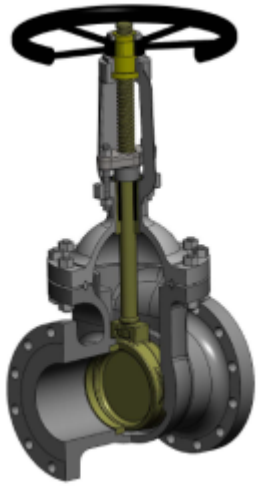
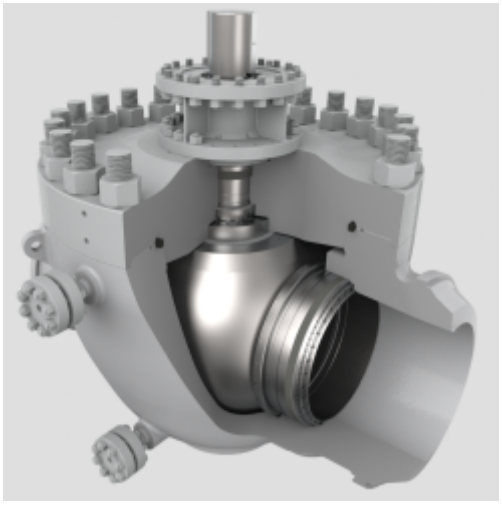
INTRODUCTION

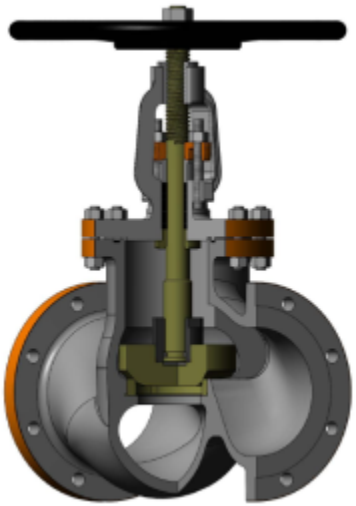
Stem seal is traditionally considered the most critical pressure containment boundary of a valve; in fact on top of the criticality of physical parameters of process fluids (Pressure, Temperature…) and its chemical aggression, stem gasket shall also withstand ***repeated dynamic strokes***.

Stroke may consist on pure linear (rising stem valves) or rotational (quarter turn valves) movement; sometimes linear and rotational movements are simultaneously combined.

Each of the above stroke movements is characterized by unique friction/wear/abrasion conditions, therefore stem gaskets may need different design features and they shall be manufactured with materials specifically selected to better suit the operations; but all the different stem gasket designs do have a unique goal: they should be, from the point of view of tightness, comparable with all other ***static*** gaskets placed on valve pressure boundary.







STEM SEAL LEAKAGES

Stem seal leakages may jeopardize surrounding environment integrity with possible impacts on both **human beings health and animal/vegetal life**
Human beings protection as well as animal and vegetal life safeguard are the main goal to be pursued.
But, in addition to the above, accidental stem leaks may jeopardize **plant operability and availability** with significant impacts on overall costs.

Health Protection
Main goals to be pursued:

- prevention of contaminants (both gaseous and liquid) release to environment which would cause serious hazard to human beings, animals, vegetal life
- prevention of possible injuries when personnel gets in contact with hot/ extremely cold poisons or aggressive leaks
- prevention of possible injuries caused by fire or explosions consequent to leakages of flammable fluids

Impact of stem Leakages on Plant efficiency (and associated costs)

- Even in case that process fluids aren't toxic or flammable, stem leaks can't generally be accepted and they shall be fixed by adequate maintenance. This, in addition to the need of special tooling, may require to run the plant with reduced capacity for some time, with consequent loss of efficiency (and costs)
- When toxic or flammable fluids are involved, maintenance may become a serious issue: tooling and protections required to carry out maintenance may become extremely complex and expensive. Furthermore, process needs to be shut down for long periods with evident production losses
- In case of toxic emissions, costs to de-contaminate the territory (with associated legal implications) are extremely high. On top of that, the local Authorities may require extended shutdown for investigations that generates further increase of plant unavailability.
- A special case are all valves installed in locations where maintenance is nearly impossible: typical cases are block valves on long pipelines or valves for deep subsea installations. It is evident that, under these circumstances, maintenance of stem gasket becomes a real challenge and implies close-to-unsustainable costs.

LEAKS DETECTION METHODS

A number of techniques are used to monitor stem leakages where either toxic and/or flammable fluids are processed.

Sensors (Sniffers)

This technique is applied to detect presence of specific gases or vapors in the environment (air). Different 'Sniffers' types are available to detect presence of various hazardous media and they are placed in critical location of the plant, in proximity of 'possible leakage occurrence' and/or in an area where accumulation of 'hazardous' media may occur.

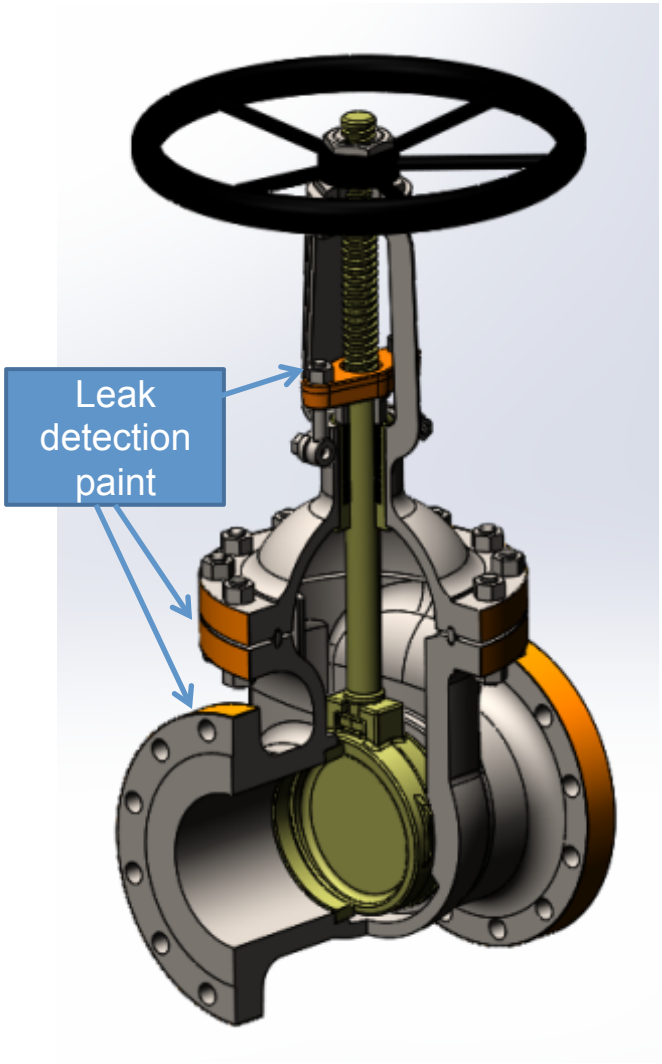
Collection of leaks from stem packing

Special (multiple seals) stem packing may be provided to collect leakages (before they 'escape' from the stuffing box) and to convey them in a safe containment. Leak-activated detectors may also be provided

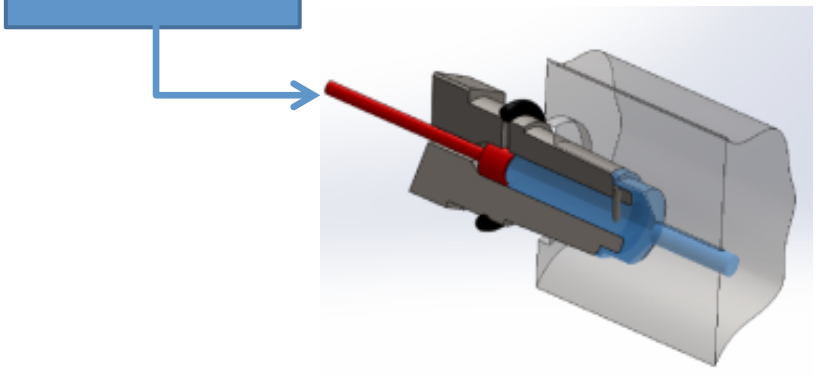
Other systems

In some applications stem packing (as well as the bonnet gasket area) are painted with special paints which change their original color in presence of specific contaminants (generally strong acids)

In any case, early detection of leaks enables preventive maintenance programs that minimize intervention costs.


Leak
detection
paint


To leak collection manifold


Visual
leak alert

STEM SEALS CONFIGURATIONS

In the recent past, while the operational parameters of industrial processes (chemical, petrochemical, power generation, hydrocarbons transportation…) were becoming more and more 'difficult 'and hazardous, the common sensibleness toward environment safeguard grew up significantly; therefore both International Standards and local Authorities put in place very severe rules and dedicated legislation aimed to protect both human beings and environment from any possible contamination.

This forced the valve industries to put significant effort to improve tightness, reliability and durability of gaskets.

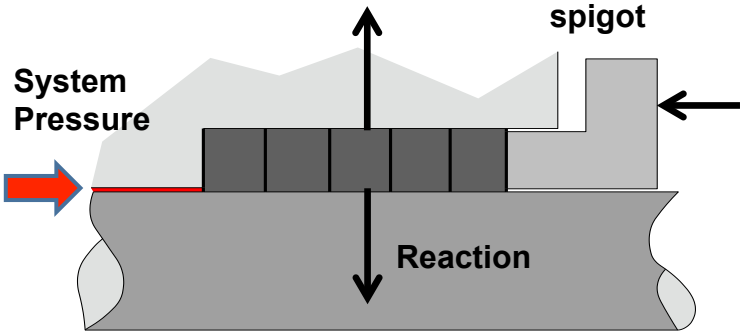
Due to its peculiar criticalities, stem gasket was subject to specific attention.

SOFT STEM SEALS

Soft seals constitute the majority of valve stem gaskets; this includes a large variety of materials like: elastomeric, polymeric (either virgin and reinforced), braided or die-formed graphite. Soft stem seals of different material and construction may be combined together to better suit the service.

The main issues when selecting a (soft) stem gasket may be summarized as:

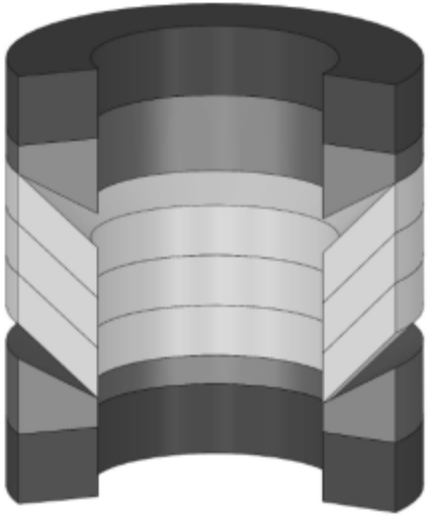
- Chemical compatibility with process fluid
- Capability of stem gasket material to safely operate under the specified combination of process design conditions (pressure & temperature).
- Resistance to Explosive Decompression (in case of high-pressure gas service)
- For control valves, operating friction and capability to withstand severe cycling shall also be considered



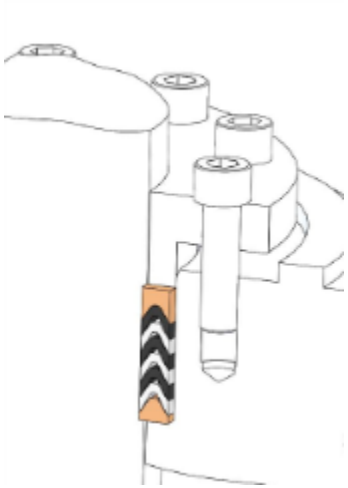
Compression Stem Packing

This gasket is made up from few turns of packing allocated in a so-called stuffing box and it is axially compressed via a gland flange.
Historically, braided asbestos-fiber-packing has been for long time the most popular stem gasket in valve industry.
Afterwards, In late seventies, asbestos has been abandoned due to its recognized health hazard.

After asbestos was abandoned, the base material of compression packing for general services moved to combination of Braided Graphite (top/bottom anti-extrusion rings) and die-formed graphite rings. This change of base material required an accurate setup in order to achieve required tightness with acceptable gland flange compression (to avoid stem blockage).
The actual 'high performance packing' are made up combining a number of cone-shaped rings
In effect, the gasket industry made available other packing materials like PTFE, or graphite/PTFE, but their use is limited in low-medium pressure/temperature.
Ceramic fiber packing are also available but their use is confined to very specific applications as they require important (and expensive) implementation of valve special features.



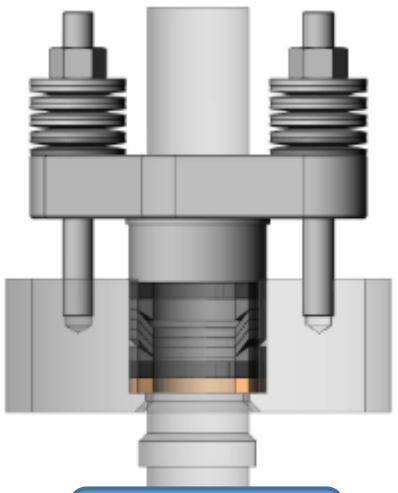
CHEVRON type stem gaskets



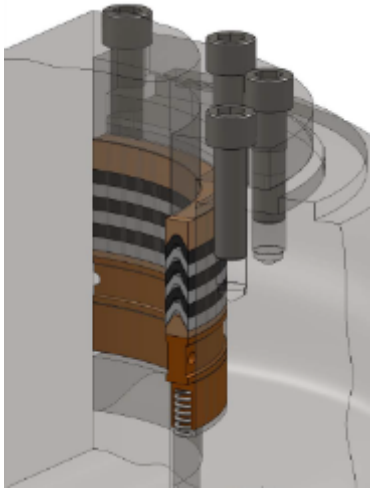
Chevron type stem gasket is in fact a particular Compression Stem Packing. The difference is that individual rings are shaped to 'wedge' to improve the overall tightness. Each ring is 'energized' (i.e.: forced to expand) by both the initial gland flange preload and by fluid pressure thrust. Individual packing ring materials are selected and combined to provide either tight seal and resistance to design pressure at design temperature. Chemical aggression of process fluid shall also be accurately considered for a correct material selection.
Most common packing ring materials are PTFE, RPTFE, PEEK

LIVE LOADING PACKING

This packing style includes some form of spring energization of packing itself. This will accommodate a wide range of variables that could affect the packing performances such as differential thermal expansion, wear, bolt relaxation, vibration, etc…
It is typically necessary to use this live-loading packing to achieve performances that will comply with various emission requirements within EPA, ISO, TA-Luft Standards

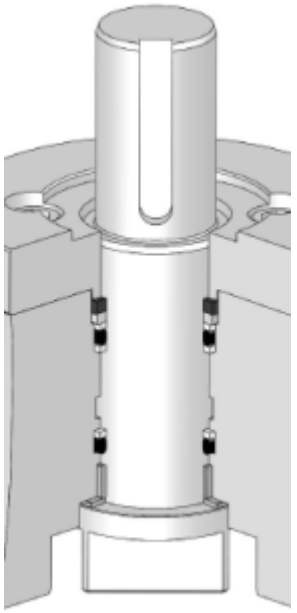


Top (bellow) Springs



Bottom (coil) Springs

ELASTOMERIC STEM SEALS

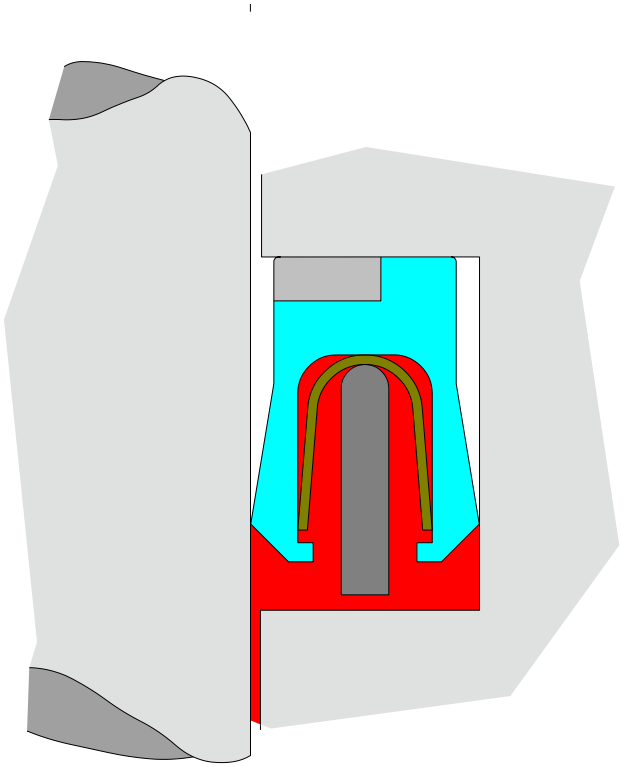


Elastomeric stem gaskets are normally supplied in form of O-Rings. Typically these are the standard stem gaskets for a wide range of quarter turn valves. In spite of their capability to provide excellent tightness, easy installation and relatively low cost, they exhibit some weaknesses that put severe limits to their applications; in fact:

- Elastomers aren't compatible with high and low temperatures. Depending on selected elastomeric compound, typical HT limit ranges from 150 °C to 210°C while LT limit is above -46°C. Normally compounds with good HT performances do not behave well in LT.
- Some chemicals, normally present in hydrocarbon, petrochemical and chemical processes may cause serious damage to elastomers
- Elastomers are subject to Explosive Decompression in HP gas service. AED materials have been developed, but still the risk hasn't been totally eliminated.
- In HP applications, particular design features shall be adopted to avoid extrusion, specially where stem motion is linear (rising stem valves). High hardness compounds are preferred for this application.

Explosive Decompression All elastomeric and few plastic materials, when in high pressure gas service, entrap gas particles that can lead to severe failures if components are subject to quick decompression. Anti Explosive Decompression (AED) elastomer grades have been developed to improve their resistance to quick decompressions. Graphite, PTFE, RPTFE, PCTFE, POPLYAMIDE and PEEK are typically ED free.

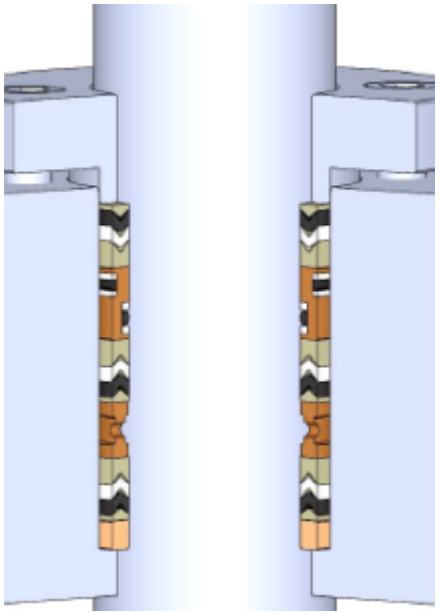
LIP SEALS



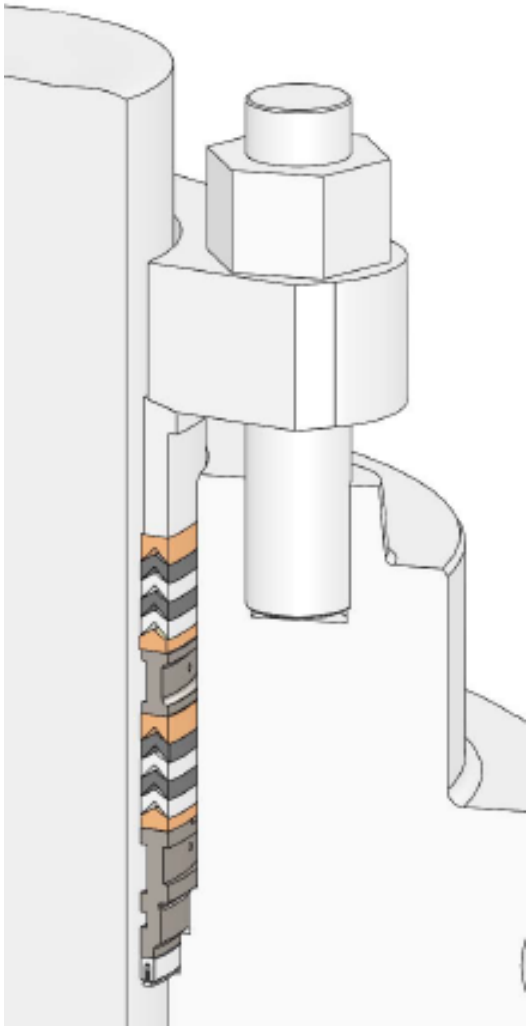
Lip seals belong to self-energizing gasket family and they are used in a large variety of applications, including stem seals.
Different spring types are used to provide pre-energization (coil springs, u-springs..).
Normally these gaskets can be made with a variety of polymers suitable to withstand a large range of chemicals; lip seals can survive to low temperatures (but not in HT) and they are not susceptible to ED; in addition, lip seals exhibit a very low friction coefficient.
The application of this gaskets is limited by both restricted tolerances and accurate surface finishing required for the seal grooves; this discourage their use when mutual differential expansion or elastic displacements are predictable for the seal housings. Another weakness of this gasket is the poor mechanical resistance of the ‘thin’ lips which are very sensitive to wear consequent to stem stroke, especially with ‘non clean’ fluids.
Due to the above reasons, lip seals are not very common in stem seal applications of rising stem valves.
When lip seals are used, it is recommended that design features to keep stem accurately aligned during the whole stroke should be incorporated

MULTIPLE STEM PACKING

This option is normally provided to improve the tightness performances and reliability of stem gasket. Multiple Stem Gaskets are based on the concept of redundancy putting in series two (or more) different gaskets eventually of different types. A lantern ring is also often provided to capture eventual leaks from the first pressure barrier and convey them in a confined safe area.

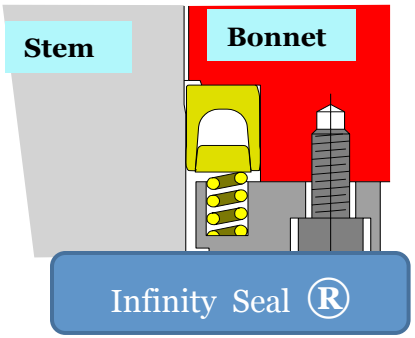


Typically, in deep subsea applications, where no maintenance can be performed, multiple stem gaskets are provided to improve the reliability through redundancy for both internal and external pressure.



METAL STEM GASKETS

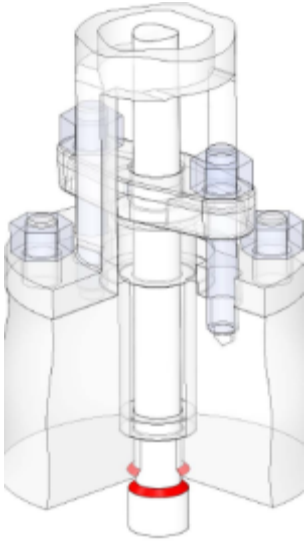
Metal stem gaskets are normally provided as additionally barrier, in series to plastic/ elastomeric stem gaskets in order to improve their reliability over extended operational life. In fact metal stem gasket life will not be affected by aging of base materials, which in fact is a typical weak point of either elastomeric and plastic materials.

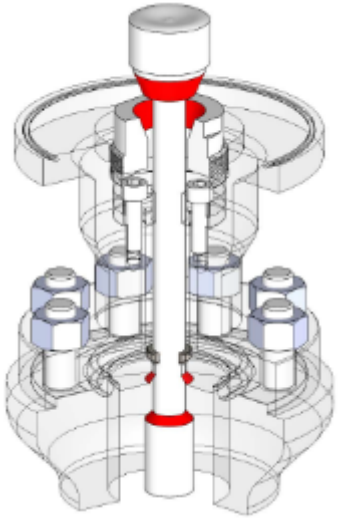


Metal stem gaskets are in general proprietary design of individual valve manufacturers and often they are protected by international patents.
These gaskets are commonly used in subsea applications or in isolation valves of long subsea pipelines.
Metal stem gaskets are normally in series to plastic stem gaskets.

Stem Backseat

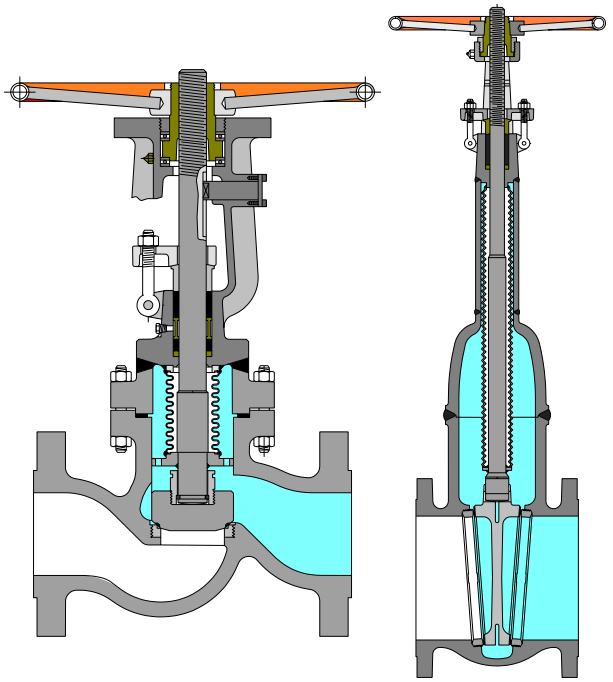
Traditionally, the rising stem valves are equipped with stem backseat that provides metal-to-metal seal with stem in upward position.
Double Backseat Metal stem gaskets can be provided for slab gates when metal stem seal is required in bot upward and downward position.

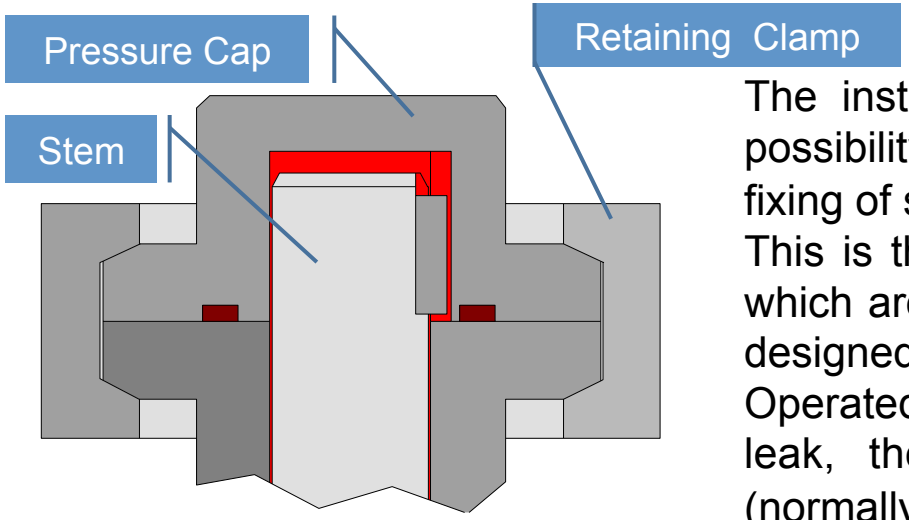




STEM BELLOW SEALS

With extreme service temperatures and/or with high-toxicity-fluids the preferred solution is the bellow seals which provide an integral metallic boundary around the stem. This design is confined to rising stem valve with a limited stroke extension: in fact the stroke shall not exceed the elastic limit of the bellow. Therefore bellow seals are mainly used or globe valve where the stroke is only a fraction of the valve seat bore; sometimes bellows are used for low/medium pressure gate valves too.





STEM CAPS

The installation of some valves prevents the physical possibility to carry out any kind of maintenance, including fixing of stem leaks.

This is the case of deep water subsea pipeline valves which are often equipped with valve-to-actuator coupling designed to enable actuator removal through Remotely Operated Tool (ROT). In case of unacceptable stem leak, the valve is moved to the required position (normally open position), than the actuator is retrieved and a pressure cap is installed. In this way the functionality of the single valve gets lost but any environment contamination will be prevented.

ASSESSMENT OF STEM SEAL TIGHTNESS (FUGITIVE EMISSIONS)

Consequently to the increased attention given to public health and environmental protection, some International Standards have been published to give common rules aimed to prevent, as far as possible, hazardous contaminations.

The evolution of these Standard was quite significant during the last three decades and it reflected both the more stringent environment-protection-legislation and the escalation of costs either to minimize loss of efficiency of plants or/and to refund eventual damages in case of hazardous contaminations.

The Standards actually used in valve industry about this subject are:

- ISO 15848 Part 1 & 2
- API 641
- API 622

ISO 15848 – Measurement, Test and Qualification Procedures for Fugitive Emissions – Part 1

This Standard enables classification of performances of different valve designs and constructions to reduce fugitive emissions; type tests for evaluation and qualification of valves are also provided. A fully assembled valve, randomly selected from production, shall be used for the test.

Only one adjustment of stem seal is allowed throughout the test.

Accepted test media are He or CH_4 @ 97% purity.

Different test classes are considered by the Standard for :

- leak rate class : A, B, C (respectively 10^{-6} , 10^{-4} , 10^{-2} mg/s*m)
- cycle class : CO1 (500 mechanical, 2 thermal), CO2(1000 mech. 1 therm.)
  For control valves number of cycles becomes 20000 (CC1) or 40000(CC2)
- Temperature classes include : -196°C, -46°C , RT, 200 °C, 400°C, but optionally any temperature class may be specified.

Extension of qualification to untested valves:

Same material, design, construction of stem

Same sealing stress

Same type of stem motion

Same tolerance class (ISO 286) and surface finish

Stem diameter within 50% and 200% of the qualified valve

Same (or lower) Pressure Class designation

Temperature within RT and higher or lower of the qualified valve

Tightness Class: equal or less of the qualified

ISO 15848 – Measurement, Test and Qualification Procedures for Fugitive Emissions – Part 2 Production Acceptance Test

This Standard provides practices to evaluate production valves whose design has successfully been qualified in accordance to ISO 15848 – Part 1

- Leaks from stem seal as well as from body gaskets are considered.
- Test medium is He @ 97% purity. Leaks are measured by sniffing method as per Part1

Different acceptance criteria are applicable for each leak Rate Class:

- Leak rate class : A, B, C (respectively 50, 100 , 1000 ppm)

Test procedure:

- One standard cycle is applicable . Leaks are measured in half open stem position at test
- beginning and after 1 cycle
- Test temperature is ambient
- Test Pressure is 6 barg

API 622 - FUGITIVE EMISSION - INTERNATIONAL STANDARD

This Standard is based on EPA 21 (Environmental Protection Agency) and it includes a Set of Test Procedures to compare various performances and properties of PTFE and Graphite based packing for both Rising and Rotating Stems in the range of temperatures of -29 to 260 °C (PTFE) or -29 to 538°C (Graphite).

Qualification is based on:

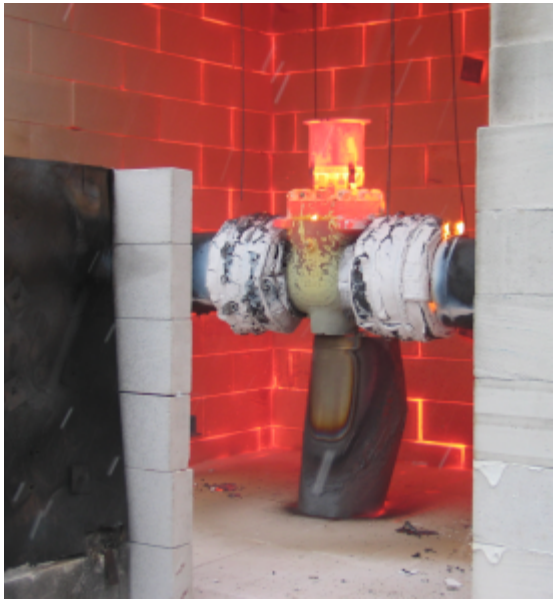
- **Fugitive emission** test @ both high and low temperature. 1510 mechanical cycles and 5 temperature cycles are included. Tests are run using standard mockups. Materials, dimensions, tolerances of the mockups are defined by this Standard. Any packing adjustments shall be recorded; leak exceeding 500ppm after adjustment causes test failure
- **Corrosion :** packing is exposed to a standard environment at both high (35 days @ 149°C and 45 bar pressure) and low temperature (28 days @ ambient or -29°C). Corrosion is evaluated on packing interfaces (stem & stuffing box mockups)
- **Packing Material Properties :**
  - Weight loss
  - Density
  - Lubricant Content
  - Leachables

API 641 - FUGITIVE EMISSION - INTERNATIONAL STANDARD

This Standard is based on EPA 21 (Environmental Protection Agency) and it includes a Set of Test Procedures to qualify PTFE and Graphite based packing for use in the range of temperatures of -29 to 260 °C (PTFE) or -29 to 538°C (Graphite).
Qualification is limited to quarter turn stem valves up to 24"Nominal Size and Pressure not exceeding Pressure Class 1500
Qualification is based on:

- **Graphitic packing (only)** shall have successfully been qualified according to API 622
- **Fugitive emission** test @ both high and low temperature. 5010 mechanical cycles and 5 temperature cycles are included. Tests are run using a complete, fully assembled, valve. Test media is Methane @ 97%. No packing adjustment is allowed during the test. Leaks shall not exceede 100 ppmv during both static and dynamic measurements
- **Valve that successfully pass the tests qualifies the following:**
  - Identical valve design (floating or trunnion ball valve, plug valve, butterfly valve)
  - identical packing material, design, sealing stress, shape and construction
  - stem diameter between ½ and two times of qualified valve
  - identical tolerance and finishing of sealing surfaces
  - packing height between 75% and 125% of qualified valve
  - valves 1 size larger, two sizes smaller
  - 1 pressure class lower and 1 pressure class higher
  - same manufacturing location (purchaser option)

Stem leak in case of fire



Valves are required to provide a safe barrier (i.e.: contain pressure and retain process fluid) even in case the plant gets invaded by a fire.
Some International Standards provide rules and test procedures to verify f the valve capability to withstand these extreme conditions.
In recent past most of fire-resistance tests for valves were based on BS6755 and API6FA
Standards; actually Quarter Turn Soft Seated Valves are normally tested and qualified according to ISO 10497.

The objective of test is to completely envelope a closed valve (filled with water) in flames to assure that the seats and sealing are exposed to high burn temperature. The heat intensity is monitored through calorimeters equipped with thermocouples. Leaks (internal and external) are monitored during the test. After the fire test, the valve body, seat and seals shall still be capable to retain the pressure.

ISO 10497 Standard also includes, after valve burning, a quick cooling down phase to simulate intervention of plant fire fighting system.
Fire Test is typically a prototype test aimed to qualify valves with identical design, and similar or identical pressure class, construction and material type (ferritic, austenitic, duplex) . Rules for coverage of qualification are provided by each Standard.